Tradeoff Analysis in Local Land Management Planning

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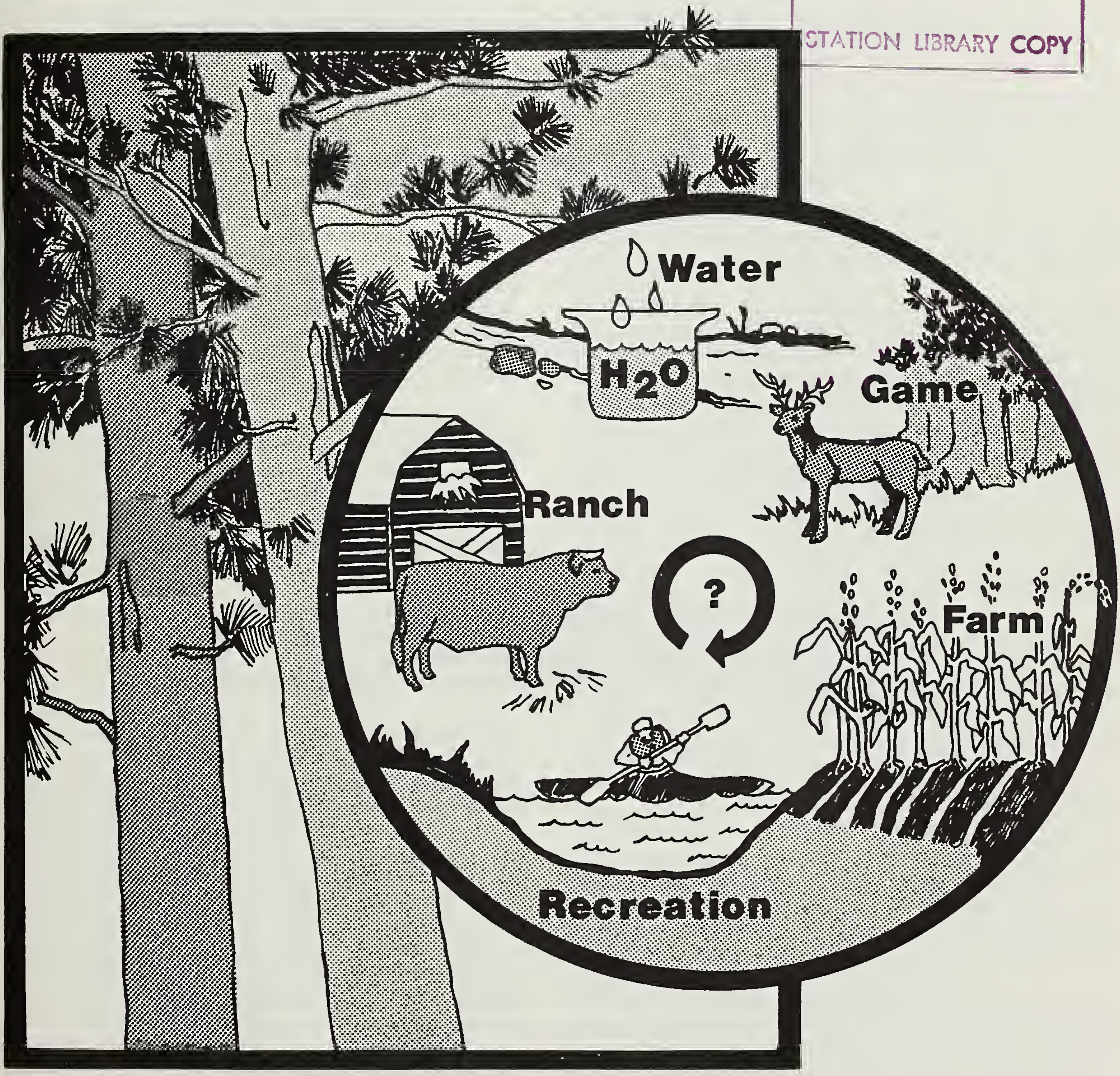

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Abstract

A set of concepts, procedures, and displays is presented to facilitate land management planning at the local level. The emphasis is on tradeoffs (analysis) in the formulation of alternatives, the estimation of the effects of the alternatives, and the comparison of the alternatives.

[1]Central headquarters is in Fort Collins, in cooperation with Colorado State University; research reported here was conducted at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University.

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Introduction

This report is concerned with comprehensive land management planning at the local level, such as on a national forest. The focus of the paper is on the systematic consideration of tradeoffs between alternatives for given resources. Within the context of an overall planning process, four critical steps in the selection and comparison of management alternatives are examined: (1) analysis of the management situation, (2) formulation of alternatives, (3) estimation of the biophysical and socioeconomic effects of the alternatives, and (4) comparison of the alternatives. Other, equally important planning steps, such as assessment of management concerns and public issues, and selection of planning criteria, are not examined here.

This report should help students, resource managers, and others particularly interested in local-level land management planning to better understand the planning process. It provides persons involved in land management with an overview of critical steps of the local-level planning process and displays to facilitate completion of those steps.

The Challenge—An Example

The following hypothetical situation is used to illustrate the kinds of information needed to arrive at a management program that will provide a reasonable mix of goods and services, both commodity and amenity, while preserving land productivity.

The "Ponderosa Forest," on public land, is the source of a river that provides water for "Pineville," a rural community at the Forest edge, and "Metro City" some distance away. The river also provides irrigation water for farmlands between the two communities.

The Forest is popular with recreationists from Metro City, and more distant places, who hike, ski, camp, fish, hunt, ride off-road vehicles, and seek wilderness experiences.

The Forest provides timber for wood products. Sawmills and other wood-related industries employ nearly 20% of the working force in Pineville.

Several family-run ranching operations near Ponderosa Forest depend on its grasslands for summer forage for their livestock. The livestock help meet the demand for beef.

The environment is diverse. Several types of soils are interspersed over the area. Shrublands and grasslands typify the lower elevations, forested slopes and meadows the middle elevations, and rocky outcrops the mountain tops. The higher elevations receive the most rain and snow.

A highway, several unpaved roads, and some off-road vehicle (ORV) and hiking trails traverse much of Ponderosa Forest, but one-quarter of the area is still roadless.

Demands for the resources from Ponderosa Forest are increasing rapidly. Some groups—even from out-of-state—want roadless areas designated as wilderness. Wood industries want timber harvested on additional areas to sustain jobs in Pineville and meet demands for wood products in Metro City and beyond. Off-road vehicle clubs want more areas designated for ORV use. Hikers want more trails closed to ORV's.

Farmers are asking for more irrigation water from streams and reservoirs. At the same time, fishermen want enough water in streams and reservoirs to safeguard fish habitats. Satisfying both would require heavy thinning of the forest to reduce water consumption by trees and thereby increase runoff.

Ranchers fear that added recreational activities will force their livestock from the range. Sportsmen want more of the range devoted to game animal habitat.

Completely satisfying all interests is impossible. A compromise lies somewhere between the diverse wants and the capacity to meet them.

Vital questions must be considered during the planning process. Where are the resources? What is their condition? How accessible are they? What are the opportunities to improve production of individual resources? How will changes in one resource affect others? Although it is not possible to answer all of the questions completely, the most current information and technology can help describe the complex interactions among the resources involved (fig. 1).

The large volume of information needed to answer such questions and the complexity of most biophysical and socioeconomic environments require a comprehensive, systematic, analytical, and interdisciplinary planning effort. To make the options understandable to decision makers and interested citizens, techniques must be used to select the most relevant information and effectively communicate that information.

The Response—Tradeoff Analysis

A plan is needed to direct future management, clearly describing any changes from recent management. Such a plan must recognize the contribution of the local area to regional and national goals, as well as to local interests. The plan should be a unique blend of efficiency and equity concerns.

One process for deciding how public land should be managed involves a focus on tradeoffs. A tradeoff is a relationship between two or more effects of a change in some condition (such as the condition of the forest). The relationship signifies a difference between the initial condition and the new one which the change would bring about. For example, a 50% increase, from the current condition of some portion of the Ponderosa Forest, in availability of snags for cavity nesting birds would cause a decrease in timber yield of 50 board feet per acre. The difference between the two conditions can be described in terms of the tradeoff between 50 board feet per acre and a 50% increase in the number of snags.

The advantage of examining tradeoffs between forest conditions is that attention is focused on actual quantities and values of those quantities rather than on abstract values. Abstract values, characterized by statements such as "timber is more important than range," generally are of little use in decision making because they do not apply to specific management options in given locations. Much more important are comparisons of, for example, the value of an increase of a certain quantity of timber with condition A to the value of an increase of a given amount of forage with condition B.

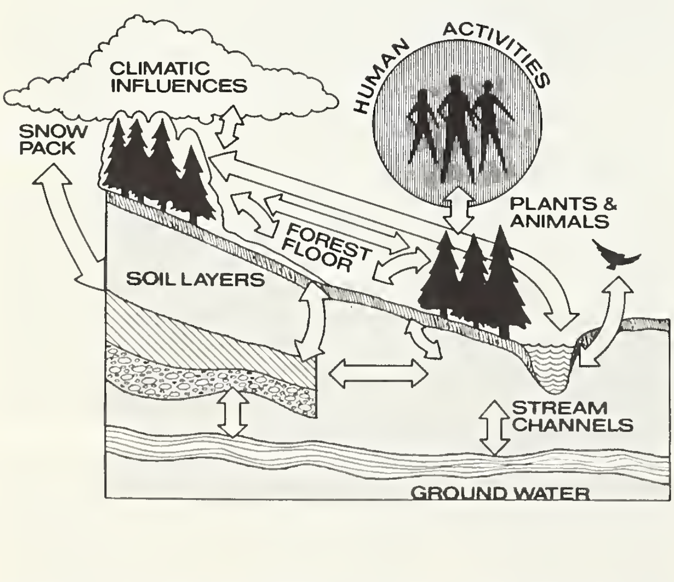

Figure 1.—Complex interactions among natural resources and uses pose important questions that must be considered in the planning process.

A process incorporating this focus involves 10 general steps:

(1) assessing management concerns, public issues, and resource use and development opportunites;
(2) deciding on planning criteria;
(3) collecting relevant data and information;
(4) analyzing the management situation;
(5) formulating feasible, realistic alternatives responsive to such assessments;
(6) estimating the physical, biological, social, and economic effects of the alternatives;
(7) comparing the alternatives and evaluating their differences;
(8) choosing a preferred alternative;
(9) implementing the alternative; and
(10) monitoring the implementation and its effects.

These steps are similar to the actions of the planning process described in the Rules for Land and Resource Management Planning in the National Forest System (USDA Forest Service 1979).

The identification of tradeoffs between the effects of possible actions is an important part of step 4, and the evaluation of those tradeoffs is necessary during the formulation of comprehensive alternatives in step 5. Tradeoffs between the effects of the alternatives are identified in step 6, and evaluated in step 7.

Several steps can be carried out concurrently, and it may be necessary to return to a step to make changes or additions. In fact, the process of steps 5, 6, and 7 can be cyclical. As step 7 comes into focus, it may become apparent that alternatives not previously considered are more realistic than those first formulated. Then the process would move back to step 5.

Public land managers are instructed to manage the land to "best meet the needs of the American people" and to consider the "relative values of various resources in particular areas" (from the Multiple Use Sustained Yield Act of 1960) in determining the needs. However, the needs and values are not determined just by observation of the public's behavior in using the public land and consuming goods and services from the land. More direct public involvement is necessary to understand the needs and values, as well as to take advantage of expertise private citizens have to offer.

Public participation is essential to the planning process. Managers must understand public issues and desires for the resources in order to formulate a set of feasible management alternatives which provides a good basis for comparison, negotiation, and compromise. The interested publics must understand the likely effects of alternative management proposals as well as the important tradeoffs in order to provide meaningful input to land managers. Concerned individuals and groups must have the opportunity to participate in working toward a compromise which accounts for important efficiency and equity concerns.

The remainder of this report focuses on steps 4, 5, 6 and 7, using the hypothetical "Ponderosa Forest."

Step 4: Analyzing the Management Situation

The goal of this step is to assess the ability of the planning area to supply goods and services to society. Goods and services are the outputs, or products, which the land, in combination with management, produces. Examples of goods for the Ponderosa Forest are timber, forage, water runoff, wildlife habitat, recreation opportunities, and wilderness preservation. Examples of services are the absorption and breakdown of pollutants and the cycling of nutrients.

Assessing the ability of the area to supply goods and services will require determining the potential, or capability, of the land under management to supply goods and services and the appropriateness or suitability of management practices, considering economic and environmental concerns and conditions.

The range of feasible output levels for specific goods and services should be determined. Feasible ranges are determined by the physical, biological, and legal capabilities of the land, and the set of suitable management practices. The capability and suitability constraints should not include any constraints which are open to question and which therefore are to be addressed in later stages of the planning process. For example, since the scenic impact of timber harvesting is an issue to be dealt with in evaluating alternatives for managing the Ponderosa Forest, care should be used in placing any esthetic constraints in determining feasible ranges of timber output at this stage in the planning process.

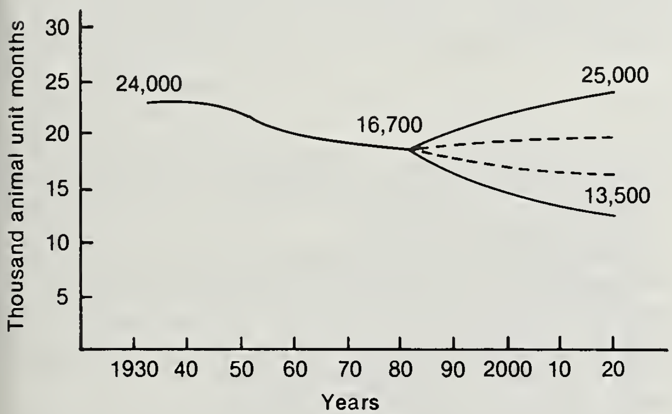

Figure 2.—Past and feasible future total annual livestock grazing on the Ponderosa Forest.

One animal unit month (AUM) is equivalent to a cow using the range for 1 month. Similarly, one cow plus one calf equals 1.32 AUM's, and a yearling equals 0.8 AUM's.

The figure shows the minimum and maximum amount of livestock grazing feasible in the future, and the rate at which these extremes can be reached. All feasible amounts assume maintenance of land productivity.

The minimum assumes gradual drops in expenditures for livestock management to the minimum necessary for maintenance of the livestock industry, designation of the roadless areas as wilderness, and maintenance of current overstory densities. The maximum assumes implementation of intensive range management practices on the most productive ranges where additional benefits are expected to exceed additional costs, and reduction of overstory densities on harvested areas by 20%. The dotted lines show minimum and maximum if all other resource outputs remain at current levels, but expenditures for range management vary as with the minimum and maximum.

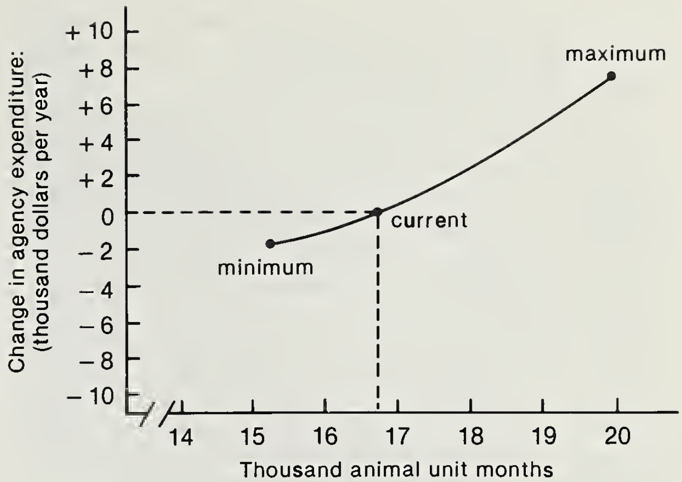

Figure 3.—Change in total agency expenditure resulting from change in livestock animal unit output from current level on the Ponderosa Forest.

It is assumed that output levels of other forest outputs would remain constant while the level of animal unit months changed. Changes in total cost with output increases are the minimum feasible. Changes in total cost with output decreases are the maximum feasible. The changes could not be made in 1 year. See the dotted line portion of figure 2 for details about the feasible rate of change.

The feasible range of output for relevant goods and services can be depicted graphically, as it is for livestock grazing on the Ponderosa Forest (fig. 2). Development of such graphs requires records of past output levels and predictions of how output will respond to management practices. The predictions can be the educated guesses of experts or the result of using more systematic prediction techniques such as computer simulation models. Such graphs should be accompanied by a list of the major relevant assumptions.

The output ranges should be expressed in terms of the cost of implementing them. Ideally, all the costs of production of a specific output would be displayed. This is a difficult task, however, because allocation of some joint (shared) costs (such as the cost of maintaining a road used for both harvesting timber and recreation) is difficult and often arbitrary. It is also unnecessary to display all costs, because the focus in formulating and comparing alternatives is on changes from the present, not on totals. A good option, then, is to display the changes in total agency costs associated with changes in specific output levels (fig. 3). For increases in output levels, the appropriate cost increases are the minimum increases which assure that capability and suitability constraints are met. For decreases in output, the cost decreases are the maximum decreases which assure that the constraints are met.

The assumptions upon which graphs such as figure 3 are based are critical. Figure 3 assumes that outputs of all other resources remain constant. A different cost

curve would apply if it were assumed, for example, that overstory (and therefore timber output, wildlife habitat, etc.) also were to change.

In addition to estimating costs of producing at various levels of output, the benefits of various output levels also should be calculated. The benefits should be expressed in monetary terms where possible (fig. 4). Otherwise they should be expressed using other appropriate scales (such as 10-point rating scales). With both cost and benefit information, the manager has a basis for determining what output level, for a given good or service, provides the greatest net public benefit. In some cases, however, non-agency costs, such as the "wear and tear" on private vehicles because of a lesser quality of road construction and maintenance, or the effect on downstream impoundments of increased erosion from forest land, have to be accounted for in addition to agency costs.

The cost and benefit information described above is calculated separately for each resource. Only the minimum necessary assumptions about other resources are made when estimating costs and benefits of a particular output level for a specific good or service. An additional set of information necessary in the analysis of the management situation is that about the tradeoffs between resources.

As with the single resource displays, development of tradeoff relationships requires predictions of how resources will respond to management actions or natural events. Prediction of these relationships generally requires the efforts of an interdisciplinary team, whose task is easier if an appropriate, computerized, multiresource simulation package is available.

Charts depicting tradeoffs can be very helpful in formulating viable alternatives. One type of tradeoff chart (fig. 5) uses individual graphs to show how specific resources might respond to changes in one element of

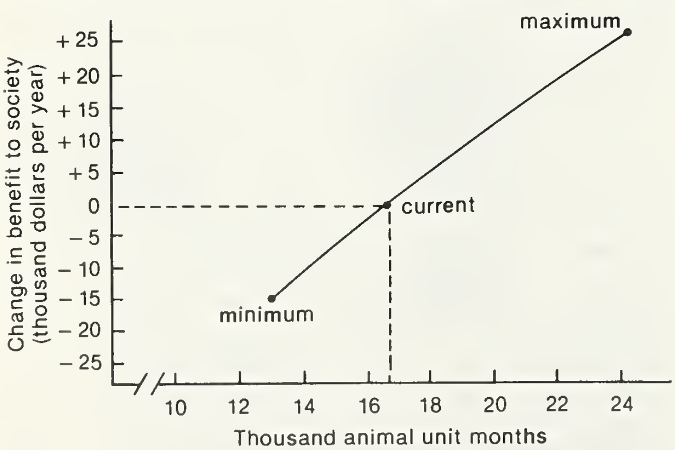

Figure 4.—Change in benefit to society resulting from change in livestock animal unit output from current level on the Ponderosa Forest.

While output levels of other resources may also change in order to bring about some of the indicated changes in animal unit output, these are not accounted for here.

The benefits are based on the value of cattle sold for meat in the market. The changes could not be made in 1 year. See figure 2 for details about the feasible rate of change.

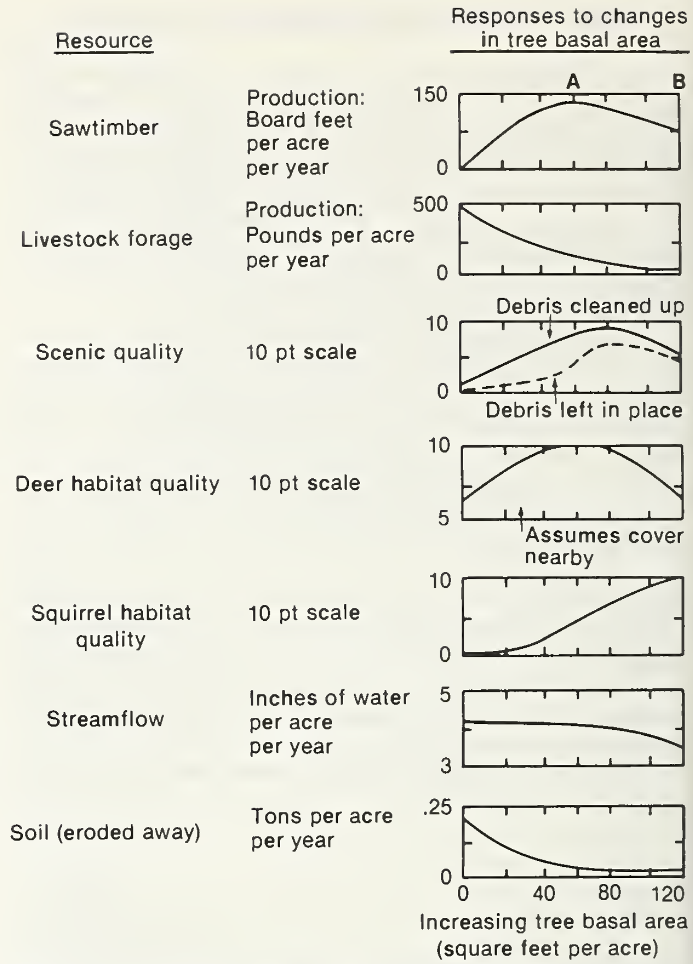

Figure 5.—Individual resource responses on ponderosa pine sites, on Brolliar soils with average annual precipitation from 20-22 inches, managed under the same set of management practices, Ponderosa Forest.

The long-term effects of managing the forest at different basal area levels can be analyzed with this chart. Tree basal area is the number of square feet occupied by living trees on 1 acre of land. Basal area is determined by measuring the cross section of the trunk of sample trees at a point 4.5 feet above ground. In most forests, the trees are not distributed uniformly. Basal area figures usually represent an average for several acres.

For example: An alternative maximizing timber yield—A—would require about 60 square feet of basal area per acre. It would result in fairly low livestock forage production and soil erosion, medium or better scenic quality depending on cleanup of logging debris, high deer habitat quality, and medium squirrel habitat quality and streamflow. An alternative to maximize squirrel habitat—B—would require about 120 square feet of basal area resulting in low streamflow, soil erosion, livestock forage, and deer habitat quality, and medium sawtimber production and scenic quality.

the forest environment—in this case, tree basal area (H. Brown et al. 1974). The chart in figure 5 represents Ponderosa Forest sites with similar soil, vegetation, and weather conditions that are managed under a single set of forest management practices. Similar charts could be developed with an element other than basal area as the common variable.

Graphs for other resources and environmental conditions could be developed and added to this chart. Many charts such as this would be necessary to repre-

sent the different environmental conditions and management practices found on a large area such as the Ponderosa Forest.

A second type of tradeoff chart combines two, or possibly three, effects in a single graph. Figure 6 shows the tradeoffs between timber production and scenic quality at various basal area levels. Scenic quality in ponderosa pine forests is closely related to tree density, but is also dependent on such characteristics as vegetation growing on the forest floor, amount of fallen trees and limbs, tree size, and density.

A similar graph (fig. 7) displays the tradeoffs between timber production and cattle grazing for a specific set of environmental conditions on the Ponderosa Forest. In addition, monetary value information is utilized to identify that point on the curve which represents the highest economic return.

Step 5: Formulating Alternatives

A set of initial alternatives is formulated considering the management concerns, public issues, resource use and development opportunities, planning criteria, and management situation, including the tradeoffs between effects of possible actions.

The alternatives must be comprehensive, integrated options; they must represent mixes of all the outputs from the planning area. One of the alternatives must represent the most likely conditions expected to exist in the future if current management direction continues unchanged. All other alternatives are considered in relation to this base alternative.

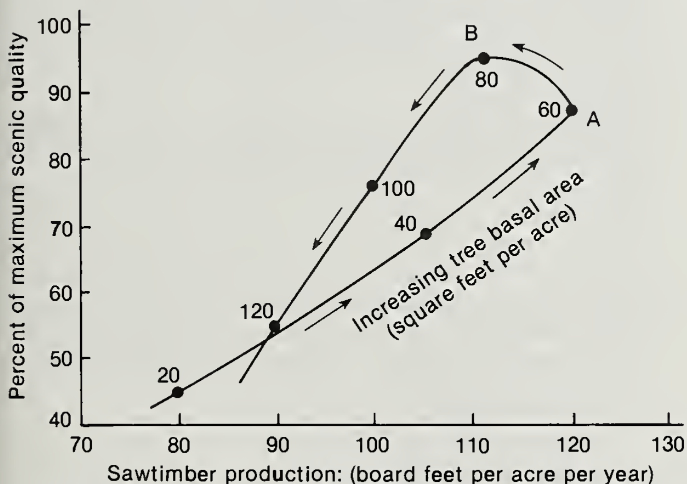

Figure 6.—Dual resource response: Ponderosa pine sites on Brolliar soils with average annual precipitation from 20-22 inches, managed under the same set of management practices, Ponderosa Forest.

Changes in scenic quality and sawtimber production are related to basal area changes on this graph. Moving along the curve in the direction of the arrows represents increasing tree basal area. The amount of vegetation on the forest floor decreases with increasing basal area. Debris from timber harvesting has been cleaned up. All sizes of trees are present.

At point A timber production is maximized; at point B scenic quality is maximized. If timber production and scenic quality are paramount, management options would aim to maintain average basal area between 60 to 80 square feet per acre. All other points on the curve represent less productive combinations of both forest products.

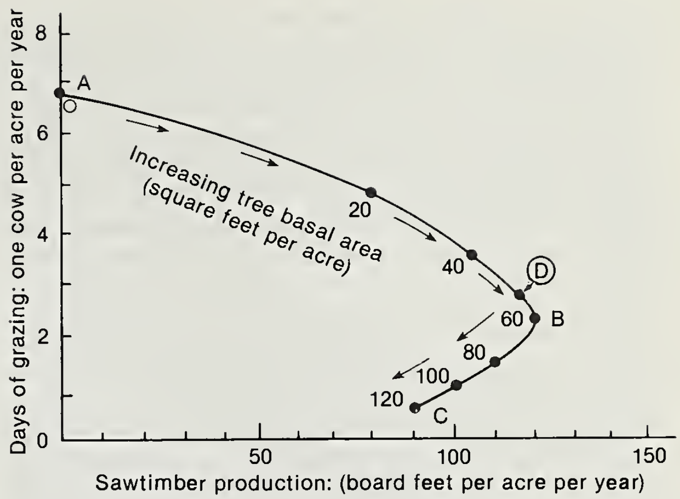

Figure 7.—Dual resource response plus highest economic return: Ponderosa pine sites on Brolliar soils with average annual precipitation from 20-22 inches, managed under the same set of management practices, Ponderosa Forest.

This figure depicts how management of a forest at various basal area levels affects grazing and timber production, and identifies a point of maximum economic return. Moving along the curve in the direction of the arrows represents increasing tree basal area; point A is no trees, point C is dense forest. As basal area increases from A to B, timber production increases while cattle grazing declines; from B to C both decline.

Economic analysis—based on price theory—provides one way to identify the most desirable combination of resource yields where the end products are sold on the open market. Assuming each point on the curve represents equal costs, the total dollar value of grazing and sawtimber in this situation is maximized at point D, where trees cover 57 square feet of basal area per acre. Managed at this level, an average acre of forest should produce 115 board feet of sawtimber, and enough forage for one cow to graze for 3 days, each year.

The set of alternatives chosen at this stage should provide a good basis for comparison and negotiation. They should not encompass the complete range of physically, biologically, and legally feasible possibilities. Instead, they should represent a reasonable range of practical options. Care must be used to not formulate alternatives which either deviate too greatly, or too narrowly, from the "current" alternative.

Comprehensive alternatives which differ both in the agency expenditure level required for implementation, and in the mix of goods and services which would be produced, are difficult to compare if all effects (both benefits and costs) are not expressed on a common scale such as dollars. This is particularly true when local citizens are asked to comment on the alternatives. For example, consider a situation where citizens of "Pineville" are asked to consider a set of alternatives of markedly different expenditure levels, where the alternative with the highest expenditure level would provide high levels of several important outputs. There may be a tendency to prefer the high budget alternative, particularly since the funds to implement the alternative would come from the national treasury.

In such a situation, little might be learned about the more relevant local issue—the relative mix of goods and services.

Where the mix is the relevant issue, all alternatives should require the same expenditure level. If alternative expenditure levels are to be considered along with alternative output mixes and all effects cannot be expressed on the same scale, each alternative output mix should be applied to each alternative expenditure level.

There is no standard approach for formulation. A common approach is to design alternatives to meet different goals, subject to a set of constraints. These goals and constraints reflect information gathered and decisions made during previous planning steps. For example, on the Ponderosa Forest, some goals to be reflected in the alternatives are to increase wood production, increase forage production, increase trail availability, improve habitat for selected species, increase water runoff, and increase acreage designated as wilderness.

Another approach is to include an alternative which maximizes efficiency, subject to a minimum set of binding constraints, along with other alternatives which emphasize equity concerns. This is a feasible approach only where all, or nearly all, of the goods and services affected by the alternatives can be assigned monetary values.

The information generated during the analysis of the management situation is very useful in formulating alternatives. For example, if a goal of one alternative were to obtain maximum sawtimber output subject to a set of constraints, charts such as figure 5 could be used. If the situation were too complicated to be adequately represented in a set of graphic displays, computerized optimization tools, such as linear programming can be used. Optimization tools are particularly useful in allocating resources to meet goals where numerous constraints must be met.

In any case, the set of alternatives should be summarized at the completion of the formulation stage based on a common set of factors such as in figure 8.

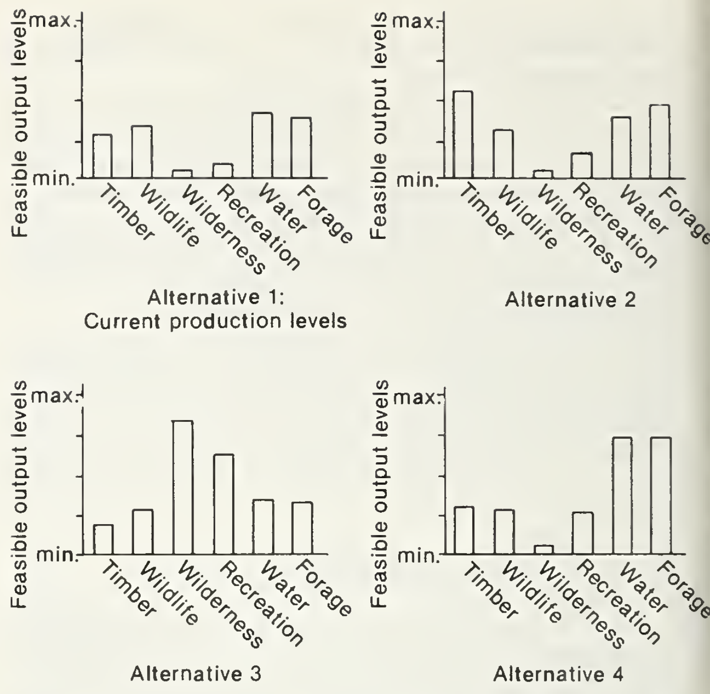

Figure 8.—Major aspects of feasible management alternatives for the Ponderosa Forest for 1980-2020.

Each graph shows six bars representing major forest resource outputs. The minimum line represents the level of output for each individual resource regardless of the outcome of the planning process. The maximum line represents the maximum physical, biological, or legal level of output for each individual resource.

Each bar represents a portion of the maximum possible yield obtainable with the respective alternative. Note that it is not possible to attain maximum output levels for all resources at the same time. Increases in one are sometimes accompanied by decreases in another.

These diagrams do not show "how much" is produced. Rather, they illustrate relative changes in production levels and set the stage for more indepth estimations of effects.

Step 6: Estimating the Effects of the Alternatives

Many of the effects of the alternatives are determined during the formulation step, in the process of designing alternatives to meet specified goals. The objective of this step is to more completely and accurately describe effects of the alternatives set forth in the formulation step. The effects of land management alternatives can be broadly categorized as efficiency-related and equity-related.

Efficiency-related effects.—These determine the efficiency of resource allocation, regardless of who gains and who pays. The most efficient allocation is that which maximizes the difference between the benefits and costs, for some set of resources. This difference between the benefits and costs is called the net benefit.

The geographical perspective for efficiency considerations is generally national, rather than regional or local. Thus, efficiency-related effects are estimated to determine how a reallocation of the nation's resources associated with a change in management direction will affect the net benefit of the nation's output; the distribution of that output is not at issue. For a discussion of the efficiency goal see Haveman and Weisbrod (1975).

Equity-related effects.—These are concerned with who gains from and who pays for resource management actions. Land management decisions may distribute benefits and costs unequally over time to favor present or future citizens; or over space to favor local, regional, or national interests; or they may favor certain social and/or income groups. Equity-related effects are generally displayed in terms of money flows, jobs and opportunities by economic sector, by geographic location, and by times when the effects occur. For a discussion of equity considerations, see Clawson (1975).

Estimating efficiency- and equity-related effects involves three steps: (1) estimating biophysical effects, (2) estimating social and economic effects, and (3) estimating the importance of the effects. Effects on the soil, water, climate, flora, and fauna are biophysical effects. Many biophysical effects affect the way people use the land, and, therefore, cause socioeconomic

effects. The biophysical and socioeconomic effects are of varied importance, or value, to people. For example, consider two alternatives which affect forest density differently over a period of years. The biophysical differences, such as the number of trees of each size left on a typical acre, habitat conditions for game and nongame wildlife species, and soil erosion rates are important. They are more meaningful, however, when translated into socioeconomic terms such as effects on jobs, scenic quality, production of wood products, and dispersed recreation opportunities. They are even more meaningful when accompanied by information about how important they are to society—about the value people place on them.

Some of the biophysical and socioeconomic effects of management, such as the effect of harvest on downed wood residues, yields of lumber, and jobs, are rather well understood. Many effects, such as the effect of harvest on some nutrient cycles and habitat for some wildlife species, are not well understood. Decisions must be made on the best information available.

Predictions of the effects are made using a variety of techniques, ranging from sophisticated computer programs with detailed field data to rules of thumb and professional judgment. For all techniques used, the predictions still are best guesses, and should be accompanied by high and low estimates for some degree of confidence. For example, the Ponderosa Forest hydrologist might conclude with 80% certainty that a given treatment will result in an average annual runoff from the area of between 46,000 and 50,000 acre feet, and that a best guess is 48,000 acre feet (table 1).

The importance of the effects is expressed using quantitative scales, such as dollars or 10-point rating scales, where possible. The importance estimates should apply to the biophysical and socioeconomic effects of the alternatives under consideration. While this seems obvious, there are at least three common pitfalls in assigning value estimates. One is to assign a value to an effect, in one location, based on values of the same effect in other locations, where the effect has significantly different values. Another pitfall is to assign value estimates without considering the actual quantities of the outputs which may be affected by the alternatives. For example, although water runoff from the Ponderosa Forest has high value in general, giving much importance to water runoff would be misleading, because the alternatives differ very little in expected runoff quantities (table 1). The third pitfall is to assign value estimates without careful examination of the use of a resource which a change in output level affects.

Table 1.—Selected effects of alternatives: average annual effects of selected outputs from Ponderosa Forest for a 40-year period—best guess and range[1]

	Alternatives			
	1	2	3	4
Sawtimber (million board feet)				
Best guess	21	27	18	29
Range	18-24	24-30	16-20	26-32
Water runoff (1000 acre feet)				
Best guess	48	48.5	48	49
Range	46-50	46-50	46-50	47-51
Forage utilization (1000 animal unit months)				
Best guess	10	23	10	27
Range	8-12	21-25	8-12	25-29

[1]*The range represents specialists' estimates of an 80% confidence interval for the best guess.*

For example, runoff from the Ponderosa Forest has numerous values to downstream users, ranging from a high value for drinking to a low value for irrigating feed grains. However, since the only use affected by a change in runoff quantity is irrigation of feed grains, it would be incorrect to value the runoff change based on its use in the municipal or industrial sectors, or even in irrigating cotton.

As with the biophysical and socioeconomic effects, estimates of importance are best guesses. Upper and lower limits to the estimates, therefore, are generally very useful. The complete set of best guesses and limits allow sensitivity analysis to help isolate the most relevant effects.

Estimating the importance of the total output of an effect is often very difficult. However, estimating the changes from the base alternative resulting from the other alternatives is usually much easier and more reliable. For example, the total value of runoff may be difficult to calculate because of most people's inability to express the importance they place on essential drinking water. However, the value of water for uses generally affected by a small change in the total runoff, such as the value of runoff in irrigating crops or lawns, is much more easily expressed, and more easily quantified using existing market data. Restricting the measures of importance to the differences between alternatives does not diminish the decision maker's ability to compare the alternatives and decide on a preferred course of action, because only the differences are pertinent for the decision. A choice between alternatives is based on the tradeoffs among the alternatives.

Consideration of the efficiency-related effects would be greatly facilitated if a common scale were available on which all costs and benefits could be compared. A common scale would simplify the job of calculating how much of one good or service society is willing to give up to receive a given amount of another good or service.

A monetary scale—dollars—is commonly used for some costs and benefits. Many resource inputs are rather easily assigned dollar values because they are budget items. Some resource outputs, such as timber, water, and forage, are often assigned dollar values because these outputs, or the products made from these outputs, are sold in relatively competitive markets. For example, in Arizona these resources have recently been valued by Kelso et al. (1973), T. Brown et al. (1974), Brown (1976), and O'Connell (1972). Some

nonmarket resources also have been assigned dollar values. For recreation examples see Brown et al. (1965), Martin et al. (1974), and Hammack and Brown (1974). The user of such dollar values must be cognizant of the basic assumptions upon which the dollar measures of value are based, such as those regarding the income distribution and the existence of market externalities.

Efforts to assign defensible dollar values to some resources have so far been generally unsuccessful. To evaluate such resources, each must be ranked on a scale of its own. Typical examples are wilderness, wildlife habitat for most species, and scenic quality. Much of the non-monetary value information, chiefly about "environmental values," is obtained using carefully worded questionnaires or observing people's behavior. See Andrews and Waits (1978) for a summary of these topics.

Where two or more products resulting from alternative management proposals can be assigned comparable dollar values, there is a partial basis for decision making, because the relative importance of some of the efficiency-related effects which each alternative produces is known. Nonmonetary-valued resources also

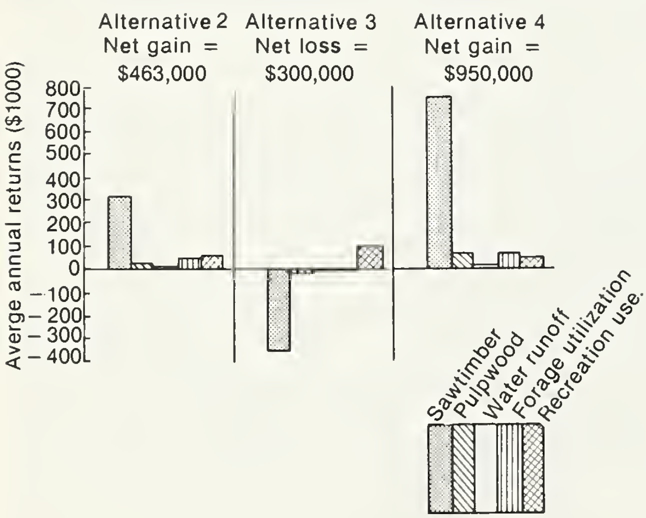

Figure 9.—Anticipated differences in average annual dollar returns over a 40-year period, comparing monetary-valued effects of alternative 1 with alternatives 2, 3, and 4 (5% discount rate), Ponderosa Forest.

This figure illustrates the major differences between the current production level—represented by the "0" line—and the other alternatives. Variations among different products are represented by bars extending from the "0" line.

In this example, when the values of the differences are compared, sawtimber is the most significant of the five dollar-valued products. Pulpwood, water runoff, forage for livestock, and recreation differ little in value. The increase in recreation for alternative 3 is insignificant when compared with the loss of timber value. For another area the situation might be different and recreation might be more important than sawtimber; only by placing the products on a common scale is this obvious.

Note that the water-forage emphasis alternative—No. 4—yields a larger discounted dollar return for sawtimber than the timber volume emphasis alternative—No. 2. A heavy initial harvest is necessary with alternative 4 to increase water and forage. Alternative 2 yields greater timber volumes in the long run.

can be compared to the monetary-valued resources for each alternative. For example, in providing habitat for a bird that nests in dense pine stands on the Ponderosa Forest, the value of the timber that will not be harvested in order to provide that habitat can be estimated. Then a decision can be made whether the habitat is worth at least as much as the timber which would not be harvested. This is called the opportunities foregone approach. (See, for example, Krutilla and Fisher 1975 or Knetsch and Fleming 1977).

Standard measures are available, such as the benefit-cost ratio and net benefit measures, to estimate the efficiency of alternatives. Where not all important costs and benefits can be assigned dollar values, however, these measures are of limited use. They can be used to compare alternatives for the set of costs and benefits expressed in dollars, but all the non-dollar-valued effects must be considered separately, or incorporated with the opportunities foregone approach. In such situations, therefore, the primary use of dollar values is similar to that of other importance estimates—simply to help decision makers understand the relative importance of the effects of alternatives. With all available information about the importance of the effects, decision makers hopefully have a sufficient basis for estimating how the alternatives to the base alternative will affect the efficiency of resource allocation.

However, where analysts can at least assign defensible upper and lower limits to the dollar values of all important costs and benefits, estimates of the changes in efficiency of the alternatives compared to the base alternative can be obtained. Such an analysis is accomplished by alternately varying one, or more, of the values while holding the others at their best guess levels. Optimizing tools such as linear programming are very useful for such sensitivity analyses.

Major results of the estimation step, in terms of best guesses, have been aggregated and summarized for a given expenditure level for the Ponderosa Forest in table 2. Alternative 1 is a continuation of current management direction. While most effects are listed as totals for each alternative, some are listed as changes from Alternative 1.

Step 7: Comparing Alternatives

Once the efficiency- and equity-related effects have been estimated, the alternatives must be compared, either to help select an alternative, or to help formulate others. The overwhelming amount of data gathered during step 6 must be condensed to a manageable set of information which describes the key differences between the alternatives. Some information necessarily is lost in the process. Experience indicates that people find it very difficult to compare alternatives on the basis of more than seven or eight effects. Including more may be more detrimental to the decision making process than is the loss of information.

The best guesses and high and low estimates of the effects and their importances provide the basis for sensitivity analyses to isolate the important effects. The

Table 2.—Ponderosa Forest: Average Annual Effects Estimated Over A 40-Year Period

	Alternatives			
	1	2	3	4
EFFICIENCY-RELATED EFFECTS				
Nonmonetary-valued effects				
Wildlife habitat for selected species (10-point scale)				
Deer	9	10	9	9
Elk	9	9	9	10
Squirrel	7	5	7	2
Turkey	10	9	10	9
Timber searching birds	7	6	7	5
Scenery (10-point scale)				
Close-up vantage points	8	6	8	4
Vista vantage points	8	6	8	6
Area of wilderness or potential wilderness (acres)	38,500	38,500	83,000	38,500
Sediment loss (tons)	500	1,130	490	1,660
Monetary-valued effects				
Benefits—physical units				
Sawtimber (million board feet)	21	27	18	29
Pulpwood (1000 cords)	17	25	15	25
Water runoff (1000 acre feet)	48	48.5	48	49
Forage utilization (1000 animal unit months)	10	23	10	27
Recreation use (1000 recreation visitor days)	50	52	60	51
Miles of hiking trail	55	42	135	42
Benefits[1]—value to society ($1000)[2]				
Sawtimber		+ 376	− 535	+ 843
Pulpwood		+ 31	− 17	+ 76
Water runoff		+ 5	− 2	+ 10
Forage utilization		+ 58	− 1	+ 73
Recreation use		+ 57	+ 98	+ 57
Hiking		− 1	+ 98	− 1
Big game hunting		+ 58	NSC[3]	+ 58
Costs[1] ($1000)[2]				
Timber management		+ 67	− 27	+ 112
Roads		NSC[3]	− 150	NSC[3]
Recreation management		− 3	+ 23	− 3
Sediment loss		NSC[3]	NSC[3]	NSC[3]
EQUITY-RELATED EFFECTS				
Monetary-valued effects				
Money flows[1] ($1000 net)[2]				
Federal government		+ 222	− 97	+ 467
Greentree County		+ 3	− 26	+ 52
City of Pineville		+ 0.5	+ 0.1	+ 1.1
Employment (jobs—full time equivalents)				
Pineville area (1980-2000)	589	706	576	798
Metro City area (1980-2000)	421	597	358	637
Community stability[1]				
Human displacement		NSC[3]	NSC[3]	NSC[3]

[1]Expressed as a change from alternative 1.
[2]Expressed as an annuity at a 5% discount rate.
[3]NSC signifies "no significant change."

most important effects are those which relate to major issues or management concerns, and clearly distinguish between alternatives.

One way to narrow the field is to compare the efficiency-related effects which are dollar-valued. The example in figure 9 emphasizes differences between the current production level and other alternatives for the Ponderosa Forest.

Wildlife effects present a particularly difficult display problem. Alternatives may differ in the effect on 10, 20, or more species. One approach is to use indicator species to represent the effect on several species, such as the use of squirrel habitat as an effect in figure 10. Another approach is to group species, and display average effects for each group (Brown 1974).

The alternatives must be displayed in terms of their important differences. One way to compare the alternatives is to display the total amount of each product estimated for each alternative (fig. 10). The example in figure 10 uses nonmonetary terms.

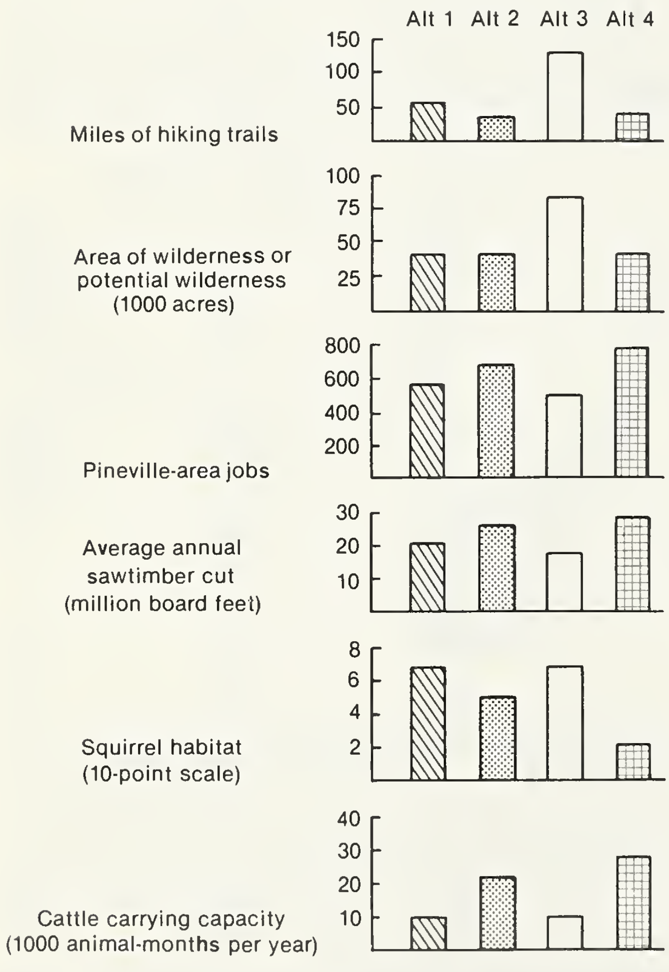

Figure 10.—Anticipated total outputs for products over a 40-year period, Ponderosa Forest.

This figure compares differences among alternatives. For example: gains in hiking and wilderness opportunities realized through implementing alternative 3 can be compared to increased timber harvest and jobs realized through implementing alternative 4.

With these facts, decision makers and interested publics can assess the tradeoffs between alternatives, and decide which values are most important.

Another display for comparing alternatives (fig. 11) uses comparative descriptions and factor profiles (Bishop 1969). The descriptions describe the base alternative and the changes from it resulting from the other alternatives, using a format and terminology designed to focus on differences and to avoid bias. The factor profiles provide a simple picture of the differences, and are suitable for some public involvement activities.

These displays (figs. 9-11) focus on tradeoffs between alternatives. They are only some of many displays which might be used in an actual comprehensive planning situation. While environmental impact statements and other planning documents abound with displays to describe alternatives, little is known about the relative effectiveness of these displays in communicating complex tradeoff information to audiences of varying interest and technical understanding.

Another factor profile tool—called the tradeoff evaluation procedure[2]—is designed for use with small groups of land managers or interested citizens. Currently being tested, this technique allows individuals to specify the amounts of one good or service they are willing to give up for a certain amount of another good or service. The technique provides one way to quantify the relative importance that any individual or group attaches to the products generated by land management alternatives—in effect, putting all such products on a common scale. Where the land management team is using the technique, it would base its importance judgments on the importance information generated during the previous (estimation) step of the process and on its understanding of the issues and political realities involved. A set of such profiles, representing major points of view, could provide the land management team with a better basis for negotiation and compromise in identifying and agreeing on a preferred alternative.

Conclusion

Comprehensive land management planning is a very complex process which depends on judgment at several critical points. Various concepts and procedures can help focus the judgments in a constructive direction. Techniques, some computer-assisted, can be used to predict the effects of alternatives, estimate the importance to society of the effects, and display the alternatives to facilitate comparison. Research is needed to improve the decision making procedures and techniques so that managers have the freedom to focus increased attention on the judgments and public involvement which no procedure or technique can eliminate.

[2] *Suhr, Lavon L. 1979. T.E.P.: A tradeoff evaluation procedure. (Unpublished manuscript, Intermountain Region, USDA Forest Service. Ogden, Utah.)*

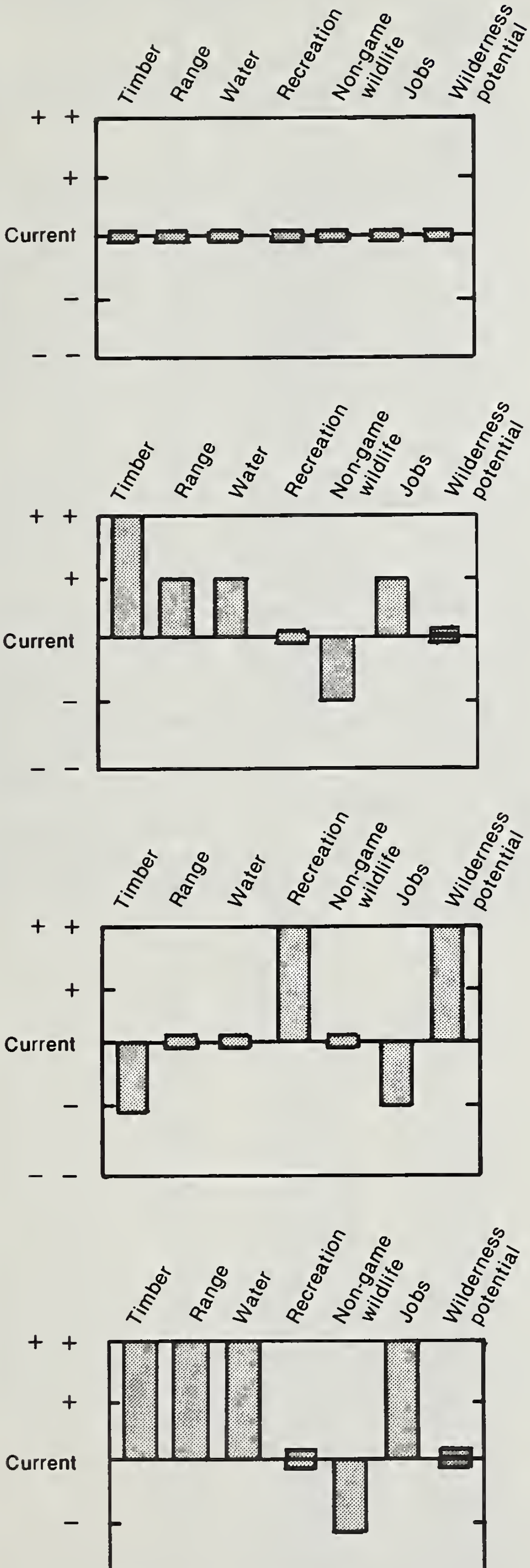

Figure 11.—Comparison of four alternatives on the Ponderosa Forest.

1. Continuation of Current Management. TIMBER—an active timber management program harvests sawtimber and pulpwood by selective cutting on a twenty year cycle. This timber supplies two sawmills and four finishing mills in Pineville. The wood products are distributed nationally. RANGE—Summer cattle range is used by three ranches to support some 2500 animals. Cattle grazing occurs on nearly all of the forest but is concentrated in the southern portion and at lower elevations. WATER—Water runoff from the forest serves the domestic and industrial need of Pineville. Approximately 70% of the water produced on the forest flows to points of use downstream of Pineville including the Metro City dam. The forest is an important source of irrigation water for farms in the area. RECREATION—Recreation opportunities include hunting, backpacking, off-road recreational vehicle use, picnicking, and pleasure driving. There are several maintained hiking trails but no developed campgrounds or picnic areas. The scenic qualities of the physical and vegetative features of the forest attract a large number of recreational users. WILDLIFE—The forest provides wildlife habitat for major deer and elk herds, as well as turkey, squirrel, rabbit, and many non-game birds and mammals. JOBS—Over one-third of Pineville's job force is directly affected by the forest. The wood industry has the greatest economic impact with recreation based trades and services also representing significant economic sources. WILDERNESS POTENTIAL—The forest contains an officially designated wilderness area and an adjacent unroaded area with virgin forests which may have wilderness potential. The current management program will harvest timber from this roadless area during the next forty years by selective cutting.
2. TIMBER production will be increased by selectively harvesting a larger percent of the trees in each area. RANGE capacity will increase as forested lands are opened. WATER runoff will increase slightly. Some types of RECREATION opportunities will decrease due to loss of a hiking trail and the scenic impact of increased timber harvesting. Other types, such as recreation vehicle use, will increase due to road improvement. Non-game WILDLIFE populations will decrease because most species of non-game birds and mammals will lose some habitat. There will be an increase in wood industry based JOBS. The POTENTIAL WILDERNESS area will be harvested by selective cutting, as planned under current management.
3. TIMBER production will decrease slightly. RANGE capacity and WATER runoff will remain unchanged from current management levels. RECREATION opportunities will increase due to additional hiking trails into the unroaded area and to several mountains and lakes. Non-game WILDLIFE populations will be maintained. Wood industry JOBS may decrease, but there may be some increase in recreation-related income. The POTENTIAL WILDERNESS area will not be used for harvests or roads.
4. TIMBER production will increase significantly over the next 20 years due to intensive selective cutting, and then decrease to approximately the present level. RANGE capacity will increase significantly as the forest lands are opened. WATER runoff will increase. Some types of RECREATION opportunities will decrease due to loss of hiking trails in the unroaded area and the scenic impact of increased forest harvesting. WILDLIFE populations for most species of non-game birds and mammals will decrease due to loss of habitat. There will be a significant increase in wood industry based jobs for the next 20 years. The POTENTIAL WILDERNESS area will be harvested by selective cutting, as planned under current management.

The four alternatives are compared here using comparative descriptions and factor profiles. The factor profiles show changes from the current management approach; therefore, all the factors are zero for alternative 1.

In most cases, the "current" or zero point on the factor profile is similar to the current average annual yield for a particular factor. For the wilderness potential factor, the "current" point signifies the progressive harvesting of the unroaded area over the next forty years.

Only non-game wildlife is shown here. Little variation among alternatives is expected for game species.

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